Imaging Attenuation in Rock with Heterogeneous Multiphase Fluids

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RESEARCH OBJECTIVES

At the center of this project is a fundamental investigation of scattering and intrinsic attenuation of seismic waves in rock with heterogeneous distributions of fluids and gas. This research represents a departure from past rock-physics studies on seismic attenuation, in that the emphasis here is not on a detailed study of a specific attenuation mechanism. Rather, the emphasis is on investigating theoretical and laboratory methods for obtaining separate estimates of scattering and intrinsic attenuation in rock with heterogeneous pore-fluid distributions. We anticipate that methods for obtaining separate estimates of intrinsic and scattering attenuation may lead to higher-resolution methods for monitoring the movement of fluids in the subsurface.

APPROACH

During the first two years of this project, we have adopted a deterministic approach to the problem of attenuation imaging. The approach is to use full-waveform viscoelastic nonlinear inversion to image the frequency-dependent viscoelastic properties of the subsurface. The complex moduli determined from this inversion provide estimates of the frequency-dependent bulk and shear moduli and the P- and S-wave intrinsic attenuation. In principle, if the finite-difference modeling code used in the full-waveform inversion scheme correctly simulates wave propagation in a heterogeneous, viscoelastic medium, and the source-receiver coverage around the medium being probed is adequate, then the apparent attenuation caused by scattering off heterogeneities is removed in the inversion process. The attenuation estimated from the inverted complex moduli will be the intrinsic attenuation. However, in practice, it is expected that cumulative scattering off subwavelength heterogeneities (e.g., layering) may also effectively remove energy from the dominant arrivals. This research will use numerical modeling with heterogeneity to investigate these issues.

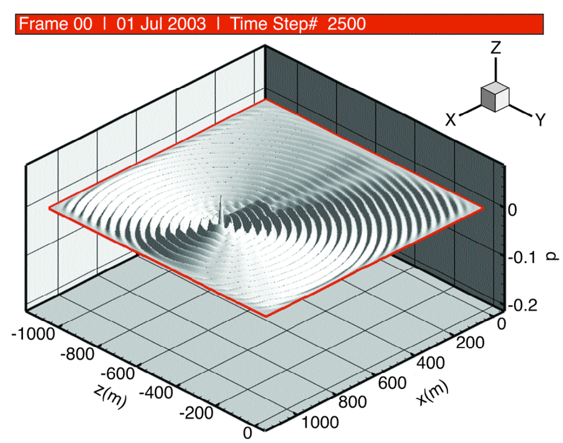

Figure 1. Snapshot of the pressure field generated by a 100 Hz pressure source located in the lower left corner of a homogeneous medium with a single fracture, located in the middle of the model. An anisotropic, viscoelastic, time-domain staggered grid was used in this computation.

ACCOMPLISHMENTS

One key component of full-waveform viscoelastic imaging is its efficient numerical algorithm for computing the seismic response at the receiver locations for multiple sources. We have found that a faster finite-difference solution for time harmonic problems can be computed with an explicit (i.e., time-domain) method rather than an iterative implicit (i.e., frequency-domain) method. In this time-domain approach to frequency-domain modeling, a time-domain finite-difference code is run with harmonic waves out to steady state (Figure 1). The magnitude and phase at each location (x,z) are extracted from the time harmonic data using a phase-sensitive detection (PSD) algorithm. Tests performed using this algorithm demonstrate that it requires a simple summation over several cycles to obtain accurate magnitude and phase estimates. Tests have also shown that the algorithm works when multiple frequencies are present in the wavefield.

SIGNIFICANCE OF FINDINGS

Based on these results, a 2-D viscoelastic, anisotropic, frequency-domain, full-waveform inversion code is being built around a 2-D viscoelastic, anistropic, time-domain, staggered-grid finite-difference code. We anticipate that this code will be significantly faster than, and capable of solving larger problems than, current viscoelastic frequency-domain inversion codes that utilize frequency-domain forward-modeling routines. We plan on completing and testing this inversion code later in 2003.

RELATED PUBLICATION

Watanabe, T., K.T. Nihei, S. Nakagawa, and L.R. Myer, Imaging of crosshole laboratory data using visco-acoustic waveform inversion and reverse-time imaging. Expanded Abstracts, 72nd Annual Meeting of the Society of Exploration Geophysics, Salt Lake City, Utah, pp. 870–873, 2002.

ACKNOWLEDGMENTS

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